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ALTERNATIVE TREATMENT TECHNOLOGY EVALUATIONS OF CERCLA SOILS AND DEBRIS

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16. ABSTRACT

In response to the Resource Conservation and Recovery Act (RCRA) Hazardous and Solid Waste Amendments of 1984, which prohibit the continued land disposal of untreated hazardous wastes, the U.S. Environmental Protection Agency (EPA) has instituted a research and regulatory development program for establishing the best demonstrated and available technology (DBAT) for RCRA and Superfund wastes. Under Phase I of EPA's BDAT research program, a representative surrogate soil containing a wide range of chemical contaminants typically found at Superfund sites was prepared for use in bench-scale evaluations of the following treatment technologies: 1) physical separation/volume reduction (soil washing), 2) chemical treatment (specifically KPEG), and 3) low-temperature thermal desorption. (Incineration and solidification/stabilization were also evaluated, but they are not discussed in this paper). In Phase II, which was conducted from June to October 1988, actual Superfund site contaminated soil and debris were used to evaluate the same technologies. This paper discusses the development of the surrogate soil and the results of the Phase I study. (Final analytical data Phase II testing were not available at this writing.)

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Alternative Treatment Technology Evaluations of CERCLA Soils and Debris Phase I Study

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In response to the Resource Conservation and Recovery Act (RCRA) Hazardous and Solid Waste Amendments of 1984, which prohibit the continued land disposal of untreated hazardous wastes, the U.S. Environmental Protection Agency (EPA) has instituted a research and regulatory development program for establishing the best demonstrated and available technology (BDAT) for RCRA and Superfund wastes. Under Phase I of EPA's BDAT research program, a representative surrogate soil containing a wide range of chemical contaminants typically found at Superfund sites was prepared for use in bench-scale evaluations of the following treatment technologies: 1) physical separation/volume reduction (soil washing), 2) chemical treatment (specifically KPEG), 3) low-temperature thermal desorption, 4) solidification/stabilization, and 4) incineration. In Phase II, which was conducted from June to October 1988, actual Superfund site contaminated soil and debris were used to evaluate the same technologies (excluding incineration). (Final analytical data from Phase II testing were not available at this writing.) This paper is one of a series of publications (see References 1 through 7) that describe the preparation of the surrogate soil and the results of the five treatability studies that were performed. This paper focuses on the results of the bench-scale evaluations of soil washing, KPEG, and low-temperature thermal desorption.

PREPARATION OF SURROGATE SOIL

More than 30,000 pounds of clean (uncontaminated) soil was prepared after considerable research into the types of soils found at Superfund sites nationwide. The final composition selected consisted of 30 percent by volume clay (a mixture of montmorillinite and kaolinite), 25 percent silt, 20 percent sand, 20 percent topsoil, and 5 percent gravel. The components were air-dried to minimize moisture and then weighed and mixed together in two 15,000-lb batches in a standard, truck-mounted, 6-yd^3 cement/concrete mixer.

Chemicals from a prescribed list of those found to be widely and frequently occurring at Superfund sites were then added to the clean soil in a series of smaller-scale mixing operations in a 15-ft^3 mortar mixer. The

organic chemicals added included ethylbenzene, 1,2-dichloroethane, perchloroethylene, acetone, chlorobenzene, styrene, anthracene, pentachlorophenol, and bis(2-ethylhexyl)phthalate. Salts or oxides of the following metals were also added: lead, zinc, cadmium, arsenic, copper, chromium, and nickel. Because concentrations of contaminants in soils vary widely, four different formulas containing either high or low levels of organics and metals were prepared for use in subsequent treatability tests involving the previously named technologies. Chemical analyses of samples of the four soils were conducted to verify contaminant levels. Table 1 presents the results of these analyses. Reserves of each surrogate soil were also packaged and archived for future use. The archived samples are being stored at EPA's R&D facility in Edison, New Jersey.

METHODOLOGY AND RESULTS OF TREATMENT EVALUATIONS - PHASE I

Physical Soil Washing

As part of the performance evaluation of this technology, samples of each synthetic soil were physically treated in a series of bench-scale washing experiments designed to simulate the EPA-developed pilot-scale Mobile Soils Washing System (MSWS). This system physically separates contaminated fines from coarse soil material, which effectively reduces the volume of the contaminated portion of the soils.

Both the design of the pilot-scale MSWS and the design of the bench-scale experiments to simulate the MSWS for cleanup of the synthetic soil samples are based on a set of assumptions that underlie the volume-reduction approach to treating contaminated soil, i.e.:

1) A significant fraction of each of the contaminants is either physically or chemically bound to the silt, humus, and clay particles.

2) The silt and clay are attached to the sand and gravel by physical processes (primarily compaction/adhesion).

3) Physical washing of the sand/gravel/rock fraction will effectively remove the fine sand, silt, and clay-sized (less than 0.2 mm) materials from the coarse material.

4) The contaminants will be removed to the same extent that the silt and clay are separated from the sand/gravel/rock fraction (i.e., increasing the efficiency of the washing process will directly increase the removal efficiency for the majority of the contaminant mix).

These assumptions were tested by evaluating different wash solutions in a series of bench-scale shaker-table experiments. Two wash solutions were chosen for evaluation: 1) a chelate solution (tetrasodium salt of EDTA, Dow Chemical Versene 100®), and 2) an anionic surfactant solution (phosphated

TABLE 1. ANALYTICAL PROFILE OF SPIKED SOILS:
AVERAGE CONCENTRATIONS FOUND UPON TOTAL WASTE ANALYSIS[a]
(mg/kg)

Analyte	Soil I (High organic, low metal)	Soil II (Low organic, low metal)	Soil III (Low organic, high metal)	Soil IV (High organic, high metal)
Volatile organics				
Acetone	4,353 (9)	356 (8)	358 (2)	8,030 (2)
Chlorobenzene	316 (9)	13 (6)	11 (2)	330 (2)
1,2-Dichloroethane	354 (9)	7 (8)	5 (2)	490 (2)
Ethylbenzene	3,329 (9)	123 (8)	144 (2)	2,708 (2)
Styrene	707 (9)	42 (8)	32 (2)	630 (2)
Tetrachloroethylene	408 (9)	19 (8)	20 (2)	902 (2)
Xylene	5,555 (9)	210 (8)	325 (2)	5,576 (2)
Semivolatile organics				
Anthracene	5,361 (9)	353 (7)	181 (3)	1,920 (3)
Bis(2-ethylhexyl) phthalate	1,958 (9)	117 (7)	114 (3)	646 (3)
Pentachlorophenol	254 (9)	22 (7)	30 (3)	80 (3)
Metals				
Arsenic	18 (10)	17 (7)	652 (4)	500 (4)
Cadmium	22 (8)	29 (6)	2,260 (2)	3,631 (2)
Chromium	24 (8)	28 (6)	1,207 (4)	1,314 (4)
Copper	231 (10)	257 (8)	9,082 (4)	10,503 (4)
Lead	236 (10)	303 (8)	14,318 (4)	14,748 (4)
Nickel	32 (10)	38 (8)	1,489 (4)	1,479 (4)
Zinc	484 (8)	642 (6)	31,871 (4)	27,060 (4)
Moisture, %	20 (7)	11 (7)	19 (3)	26 (2)

[a] Values in parentheses indicate number of samples analyzed.

formulation from Procter & Gamble, Institutional Formula Tide^{R}). Following the shaker-table washing, each synthetic soil was wet-sieved to separate the fines from the coarse material. Although the EPA MSWS only separates the soil into >2-mm and <2-mm size fractions, three size fractions (>2-mm, 250-µm to 2-mm, and <250-µm) were investigated in this study to determine if the middle fraction (medium to fine sand) could be cleaned effectively and thereby increase the potential volume reduction. The results are presented in Tables 2, 3, and 4.

In summary, the results support the basic assumptions underlying the volume-reduction approach to soil decontamination; that is, a significant fraction of each of the contaminants is attached to the fines (silt, humus, and clay), and the coarse material (sand and gravel) can be cleaned by physical separation from the fines. The data indicate that 1) water alone can efficiently remove a significant portion of both the organic and inorganic contamination from the ≥2-mm soil fraction of a freshly contaminated soil, and 2) the addition of a chelate can enhance metals removal from the middle (2-mm to 250-µm) and fine (<250 µm) soil fractions.

Chemical Dechlorination/KPEG

Chemical dechlorination was examined as a treatment technology because it had already been successfully demonstrated at laboratory scale with soils and sludges contaminated with polychlorinated biphenyls (PCB's) or dioxins and was viewed as a promising treatment technology for further development to pilot scale and possibly full scale. The KPEG dechlorination process involves the application of a potassium hydroxide-polyethylene glycol reagent to contaminated soil at elevated temperatures for a period of 2 to 4 hours, after which the reagent is decanted and recovered and the soil is rinsed and neutralized. The reagent strips one or more chlorine atoms from the PCB or dioxin molecule and forms an inorganic chloride salt and a derivative of the PCB or dioxin, which theoretically should be less toxic than the original contaminant.

Each of the four synthetic soils were evaluated in this study. Although the soils did not contain any PCB's or dioxins, other chlorinated species were present, and learning whether these compounds could be dechlorinated was of interest. Also of interest was learning whether the process might effectively remove other organic and inorganic contaminants present in the test soils.

Overall results of the KPEG tests are presented in Table 5. The analyses showed that the KPEG process was very effective in removing the volatiles from all four soils. Removal rates for all volatiles exceeded 90 percent in all tests, and usually ranged from 98 to >99 percent. Mass balance data (not presented) strongly indicated, however, that most of the volatiles were unaffected chemically by the treatment and were removed strictly by volatilization processes. Notable exceptions to this were 1,2-dichloroethane and tetrachloroethylene, which appeared to have been completely destroyed by this process.

Semivolatile results are available for only anthracene and pentachlorophenol. In the case of pentachlorophenol, the data indicate it was removed

TABLE 2. SOIL WASHING EFFECTIVENESS (>2-mm SIZE FRACTION) - OVERALL PERCENTAGE REDUCTION BY CONTAMINANT GROUP[a]

	Soil I (high organics, low metals)		Soil II (low organics, low metals)			Soil III (low organics, high metals)		Soil IV (high organics, high metals)		
	Water	Surfactant	Water	Surfactant	Chelate	Water	Chelate	Water	Surfactant	Chelate
Volatiles	>99.9	>99.8	99.9	99.9	>99.9	>99.9	99.9	>99.9	99.9	>99.9
Semivolatiles	98.9	>99.8	93.9	93.5	90.1	>94.8	96.4	97.8	>98.3	97.8
Metals	92.2	91.5	>96.7	95.7	95.9	98.0	98.4	97.1	98.4	98.1

[a] Total waste analysis.

TABLE 3. SOIL WASHING EFFECTIVENESS (250-μm to 2-mm SIZE FRACTION) - OVERALL PERCENTAGE REDUCTION BY CONTAMINANT GROUP[a]

	Soil I		Soil II			Soil III		Soil IV		
	Water	Surfactant	Water	Surfactant	Chelate	Water	Chelate	Water	Surfactant	Chelate
Volatiles	99.8	99.8	>99.9	>99.8	>99.9	>99.3	99.0	>99.7	>99.7	>99.7
Semivolatiles	56.2	65.6	52.7	47.3	67.5	0	0	0	29.4	32.3
Metals	81.6	80.7	>82.7	91.6	85.1	96.4	98.4	90.7	91.8	90.3

[a] Total waste analysis.

TABLE 4. SOIL WASHING EFFECTIVENESS (<250-μm SIZE FRACTION) - OVERALL PERCENTAGE REDUCTION BY CONTAMINANT GROUP[a]

	Soil I		Soil II			Soil III		Soil IV		
	Water	Surfactant	Water	Surfactant	Chelate	Water	Chelate	Water	Surfactant	Chelate
Volatiles	66.2	88.0	>99.8	>99.4	99.6	86.7	>93.2	>69.6	95.0	81.8
Semivolatiles	59.7	43.2	0	0	0	0	0	0	0	0
Metals	0	0	0	0	21.9	0	78.2	0	7.3	82.2

[a] Total waste analysis.

TABLE 5. KPEG EFFECTIVENESS - OVERALL PERCENTAGE REDUCTION BY CONTAMINANT GROUP[a]

	Soil I		Soil II		Soil III		Soil IV	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Volatiles (all)	99.9	98.3	98.2	96.3	99.5	97.5	99.9	98.1
Semivolatiles								
Anthracene	91.3	96.3	75.6	-10	-490	-1246	96.0	97.0
Pentachlorophenol	98.1	97.7	91.9	94.5	99.6	99.0	95.8	95.4
Metals (all)	44.5	-[b]	39.4	-	49.4	-	29.3	-

[a] As measured by total waste analysis. A negative percent reduction results when chemical analysis of a treated residue yields a higher contaminant concentration than the untreated material.

[b] No data collected.

from the soil at efficiency levels ranging from 92 to 99 percent; however, the mass balance data indicated that it was not dechlorinated by the KPEG reagent. Anthracene also was not destroyed. Removal efficiency data for the compound are somewhat equivocal, possibly because of analytical limitations associated with recovering anthracene at these levels in soils.

The KPEG process demonstrated only limited success in the removal of the inorganic contaminants from the soils. Overall removal rates ranged from 29 to 49 percent.

Low-Temperature Thermal Desorption

The purpose of this research was to investigate the capability of laboratory-scale, low-temperature thermal-desorption technology for removal of volatile and semivolatile contaminants from the soils. The laboratory testing program consisted of 15 separate bench-scale tests (10 in a tray furnace and 5 in a tube furnace). Only Soils I and II were tested. Temperatures of 150°, 350°, and 550°F were evaluated for 30 minutes to determine how each temperature affected removal of the contaminants. The tray furnace was used as a baseline technology to determine the overall effectiveness of thermal desorption in removing contaminants from the soil. The tube furnace was used to provide additional data on the concentration of contaminants in the off-gas in an attempt to establish a material balance.

Table 6 shows the overall results of the tray tests of Soils I and II. The studies showed that >95 percent of the volatiles were efficiently removed from the soil at all temperatures. Removals of semivolatiles were less efficient than removal of volatiles at 150° and 350°F, but removal efficiencies tended to increase with temperature and approached the 90 percent efficiency range at a temperature of 550°F. The apparent increase in metal

concentrations in the residues (as indicated in the negative reduction values) may be an artifact in the data resulting from moisture losses during heating. Because the soils contained 6 to 17 percent moisture before treatment, the moisture loss tended to produce a higher metal-to-soil ratio (i.e., concentration) in the treated residual, which results in an apparent (but unreal) increase in metal content. A second factor that may have contributed to the change in metals concentration was a change in the matrix's ability to retain metals after heating.

TABLE 6. LOW TEMPERATURE DESORPTION - OVERALL PERCENT REDUCTION OF CONTAMINANTS BY GROUP AT VARIOUS TEST TEMPERATURES WHEN TRAY FURNACE AND 30-MINUTE RESIDENCE TIME WERE USED[a]

	Soil I			Soil II		
	150°F	350°F	550°F	150°F	350°F	550°F
Volatiles	97.8	99.8	99.8	98.3	95.9	96.0
Semivolatiles	-5.3	41.6	93.6	11.7	74.8	86.3
Metals	-9.3	-12.1	-15.1	5.1	10.2	-7.3

[a] As measured by total waste analysis. A negative percent reduction results when chemical analysis of a treated residue yields a higher contaminant concentration than the untreated material.

SUMMARY AND CONCLUSIONS

The research program produced a valuable and interesting new data base that outlines the results that can be achieved by treating a synthetic contaminated soil with several bench-scale treatment technologies. This paper only highlights key portions of the data base; it is by no means complete. Detailed reports covering the complete findings of each study are available through EPA's Risk Reduction Engineering Laboratory in Cincinnati (see Acknowledgments).

The preparation of synthetic soils is viewed as a particularly valuable segment of the research because this had never before been attempted on such a large (volumetric) scale. Methods of mixing both the basic clean soil and the contaminated material were developed and found to produce a quality product with good homogeneity. This allowed each of the treatment technologies to be operated with a high degree of assurance that the starting materials were essentially identical from one test to another.

The effectiveness of each treatment technology on the four soils can be summarized as follows. The low-temperature thermal desorption effectively reduced the volatile organic fractions (greater than 97.9%). The chemical treatment (KPEG) operated on most of the semivolatiles with greater than 90 percent reduction effectiveness. Greater than 98 percent of the volatile organic compounds were removed, but this was probably due to volatilization

during the test runs. Soil washing provided the best metals-reduction technology across all the soils; metals reduction averaged 93 percent for the top two soil fractions. Soils washing was also very effective in reducing the volatiles (average reduction of about 99%) for the top two soil fractions. The semivolatiles were reduced an average of 96 percent for the >2-mm soil, however, the semivolatiles were only reduced an average of 35 percent for the 2-mm to 250-μm fraction.

Phase II of the CERCLA BDAT Research Program was initiated in 1988 and is continuing. Soils from actual Superfund sites have been collected and tested for treatment effectiveness by using the same bench-scale procedures as in Phase I. Results, which are expected to be available in late 1988, will be compared with those produced on the synthetic soil formulas.

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Thermal desorption	IT Corporation Knoxville, Tennessee (subcontractor to PEI Associates	68-03-3389 Work Assignment 0-5	Robert C. Thurnau

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REFERENCES

1. Locke, Esposito, Furman, and Traver. CERCLA BDAT Standard Analytical Reference Matrix Preparation and Results of Soil Washing Experiments. Presented at HMCRI Annual Conference on Hazardous Wastes and Hazardous Materials, Las Vegas, Nevada, April 1988.

2. Esposito, M. P., B. B. Locke, J. S. Greber, and R. Traver. CERCLA BDAT Standard Analytical Reference Matrix (SARM) Preparation and Results of Physical Soils Washing Experiments. Presented at the 14th Annual EPA Research Symposium: Land Disposal, Remedial Action, Incineration and Waste Treatment of Hazardous Waste, Cincinnati, Ohio, May 1988.

3. Esposito, P., J. Hessling, B. B. Locke, M. Taylor, M. Szabo, R. Thurnau, C. Rogers, R. Traver, and E. Barth. Results of Treatment Evaluations of Contaminated Soils. Presented at the 81st Annual Meeting of the Air Pollution Control Association, Dallas, Texas, June 20-24, 1988.

4. Esposito, M. P., M. L. Taylor, C. L. Bruffey, and R. C. Thurnau. Incineration of a Surrogate Superfund Soil Using a Pilot-Scale Rotary Kiln System. Presented at the 3rd Chemical Congress of North America/195th ACS National Meeting, Toronto, Canada, June 5-10, 1988.

5. Thurnau, R., and P. Esposito. Results of TCLP Work Completed on Different Treatment Technologies for a CERCLA Synthetic Soil. Presented at the 14th Annual EPA Research Symposium: Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Cincinnati, Ohio, May 1988.

6. Szabo, M. F., R. D. Fox, R. Thurnau. Application of Low Temperature Thermal Treatment Technology to Hazardous Waste. Presented at the 14th Annual EPA Research Symposium: Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Cincinnati, Ohio, May 1988.

7. Weitzman, L., L. G. Hamel, and E. F. Barth. BDAT for Solidification/Stabilization Technology for Superfund Soils. Presented at the 14th Annual EPA Research Symposium: Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Cincinnati, Ohio, May 1988.